COMPARATIVE CHRONOLOGY.[1]

BY W J MCGEE.

I.—*Natural Time-Units.*

The earth rotates on its axis, and day is born of the night and runs its course of sunshine; and it is a "sun" or day. The earth revolves about the sun, and summer is born of winter and gradually cools again; and the cycle is a year. These are the solar periods of the savage and the philosopher.

Our satellite revolves about the earth, and its light waxes and wanes and then goes out; and from dark to dark is a "moon" or lunation of 29½ days. This is the lunar period of the nomad and the astronomer.

The earth and moon pursue their paths through space, and sometimes the moon passes athwart the face of the sun while again the earth's shadow darkens the moon, and there is an eclipse; now while the eclipses of any year do not correspond with those of the next year or of the last, yet earth and moon are so related in space that after 223 lunations, or about 18 years, the cycle of eclipses is repeated; and this eclipse cycle is a Chaldean saros.[2] When the earth completes a revolution about the sun and four seasons have passed, the place of the moon is not the place occupied at the beginning of the year, for the lunar and solar cycles are not commensurable; but, as the revolutions run, the new year and new moon first diverge and then converge until at the end of 235 lunations, or 19 years, they nearly coincide again; and this cycle is the tchang of China or the Metonic cycle of ancient Greece, the source of our Golden Number and the basis of the ecclesiastic "movable festivals" of modern times. At the end of four of these 19-year periods the moon returns still more nearly to the initial place, and this longer

[1] Read before section H of the A. A. A. S., at Rochester, August 22, 1892.

[2] Modern observation, combined with the Newtonian theory, has corrected this and other primitive empiric periods.

cycle of 940 lunations or 76 years is the Callippic cycle of ancient Greece, known long before in China. Then as tchang succeeds tchang and generations of men grow old and die, the moon oscillates about the new year until the satellite has circled the earth 7,421 times and 600 years have come and gone, when the initial relation is so nearly restored that only refined observation or correct theory can detect the difference; and this long cycle is the Chaldean naros. But even the naros is not the end; for after 243 tchang, or 57,105 lunations, or 4,617 years, the old positions are almost exactly restored and also conjoined with an arbitrary time-unit of 60 days;[1] and this longest cycle of primitive observation, at the same time one of the most marvelous of human achievements and the most significant historical evidence of human antiquity, is the Chinese Great Year. These several cycles are the lunisolar periods on which most ancient and many modern calendars are based.

The earth rotates as it revolves about the sun, and the synodic year beginning at noon ends at nightfall, for the periods of rotation and revolution are not commensurable; after four years have passed the star rising with the sun on the new year is near the rising sun on the second day of the year, but it is not until 1,461 winters have melted into summer that the sunrise star of a full-day calendar again rises with the sun on new year's day; and this is the Egyptian Sothic cycle. The earth bulges at the equator and the equatorial protuberance is attracted by sun and moon in such manner as slowly to shift the seasons as the years come and go until winter becomes summer and summer winter at given dates on each portion of the globe; this secular shifting of the seasons, or precession of the equinoxes, waxes and wanes again through a cycle of over 25,000 years[2] and forms a Platonic year. These cycles may be called siderosolar periods, since they are determined through the aid of the fixed stars.

The several cosmic movements and the solar, lunar, lunisolar, and siderosolar cycles through which they run yield the so-called

[1] According to Houzeau: Bibliographie générale de l'Astronomie, par J. C. Houzeau et A. Lancaster, tome premier, première partie, 1887 (Introduction), p. 95.

[2] The mean cycle is 25,694.8 years, with a secular inequality of 281.2 years, as computed by Stockwell: Secular Variations of the Elements of the Orbits of the Eight Principal Planets (Smithsonian Contributions to Knowledge), 1872, pp. xii, 175.

"natural time-units," and represent the bases of calendars and chronology. Summarized in tabular form they are:

Solar period.....	Sun or day.
" "	Summer or year, 364¼ days.
Lunar period	Moon or lunation, 29½ days.
Lunisolar period....	Saros (Chaldean eclipse cycle), 18 years, 223 lunations.
" "	Tchang or Metonic cycle, 19 years, 235 lunations.
" "	Callippic cycle, 76 years, 940 lunations.
" "	Naros, 600 years, 7,421 lunations.
" "	Chinese Great Year, 4,617 years, 57,105 lunations.
Siderosolar period ..	Sothic cycle, 1,461 years.
" " ..	Platonic year, 25,694.8 years.

All of these cosmic cycles were observed by primitive peoples (though the precession of the equinox was perceived only as a linear movement). The rudest savage regulates his activities and reckons his journeys by suns; all pastoral nomads reckon time by moons, and some develop lunar calendars; the fruit-eater and the forerunner of the farmer reckoned by the march of the seasons, and various groups in different parts of the world developed solar calendars. The night-watching herdsmen of the Chaldean plains revered new moons and marveled at eclipses for unnumbered generations until they established the saros and naros; the flood-taught fellahin of the Nile immortalized the annual inundations in traditions and hieroglyphs, and full 5,000 years ago wrought out the sacred Sothic cycle of a millennium and a half, and their sages measured a part of the Platonic precession; untold millenniums past the patient rice-growers of the Yellow river watched the wanderings of earth and moon until they succeeded in establishing, long before the beginning of our era, a cycle similar to that forming the basis of our own ecclesiastic calendar, and a far greater cycle approaching in duration the entire term of extant written history; even the ancient Aztecs of our own continent had, according to Houzeau, a lunisolar calendar more exact than the Julian calendar.[1]

The shorter of these cycles are recognizable in the childhood of individuals and of races; the longer are so great as almost to baffle realization. They may be made appreciable by comparing them with familiar space units: Let a day be represented by a thick

[1] Bibliographie générale de l'Astronomie, op. cit., p. 92.

pen-stroke, a thirtieth of an inch across; then, a lunation will be an inch, a year will become a foot, a saros will extend over a rod, and a Callippic cycle will be longer than a surveyor's chain. On the same scale, a naros will stretch into the conventional rifle-shot of 200 yards, the Sothic cycle will be over two furlongs, and the Chinese Great Year nearly a mile, while the Platonic year will become five miles.

Such are the natural units by which mankind have ever sought to measure time.

II.—*Artificial Units and Eras.*

Time is commonly classed as one of four fundamental conceptions to which all other conceptions may be reduced; for Energy is manifested through Matter disposed in Space and acting through Time. But, on analysis, time (and perhaps space) would seem ancillary to energy, since the conception of motion involves not only the spatial quantity through which the points or particles move, but a correlative quantity extending from the beginning to the end of the movement. If this is so, the idea of time springs from the sequence of events or stages in that movement of points or particles which is comprehended under the term energy. Then time may be characterized as the *order* and space as the *direction* of cosmic energy, and, so far as this definition is concerned, it boots not whether matter and energy are essentially one or intrinsically distinct.

It is important that the conception of time should be clearly defined; for by definition it may be either excluded from or included within the domain of science. Poets and dialectic philosophers teach the infinite uniformity of time just as they once taught the infinite divisibility of matter, and thus relegate the conception to the realm of the supernal, far beyond the reach of actual experience; but, if the conception can be reduced from the ideal to the real and definitely correlated with the more exact and hence more refined conceptions concerning energy and matter, a vantage point for research will be gained. In poesy and dialectics time is absolute, extra-physical and unknowable; as characterized above, time is relative, a manifestation of energy or matter-energy, and a subject of exact knowledge. The dialectic conception of time is hazy and its origin is shrouded in mystery; under the physical characteriza-

tion the conception is definite and stands for actual experience, individual and inherited—it is a composite picture, made up of a vast series of actual percepts and concepts. In lax ideation time is the perfect standard of which theorists dream; in exact thought orbital revolution is the gold and axial rotation the silver of the cosmic bank of time, but the measures are neither commensurable nor constant, and all other values must be adjusted to them arbitrarily. So the conception of time may be defined as the sum of experiences concerning the order of motion, *i. e.*, concerning the sequence of position.

Conceiving time as ancillary to energy or matter-energy, and thus as an expression of the motion of points, particles or masses, it may be relatively measured in different ways, depending on the nature of the motion: It may be measured by linear motion, and indeed has been so measured by observation on falling bodies and by the clepsydra and the hour-glass; it may be and is commonly measured by rhythmic or reciprocal motion, as in the pendulum; and it may be measured by cyclic or rotary motion, and this has been done from the beginning of human existence through observation on the sun, moon, and stars. Of these methods the last is the best, and the first the least useful; linear motion is neither uniform nor persistent, rhythmic motion is more orderly and persists longer, while cyclic motion is far more orderly and persistent than either. Yet even cyclic motion is variable, since orbits are eccentric and one part and another of the cosmic mechanism thus runs fast and slow alternately; there is indeed no uniform process in nature; and the measure of time is simply the aggregate or mean of certain observed motions expressed in arbitrary terms.

In measuring time by cyclic motion a difficulty arises with the effort to fix arbitrary limits for the limitless cycles; and moreover the cycles themselves are in some degree illusory: To an observer on the moon the shadow of the Andes would indeed sweep across the face of the earth, but meantime the body of the earth would move many times further; to an observer on the sun, the moon would, it is true, stand sometimes on this side of the earth, sometimes on that, but meantime both would move many times the length of the minor orbit, and the satellite would seem simply to pursue a serpentine path; and an observer at a thousand times Neptune's distance might see the entire solar system spin through space at a rate far exceeding that of either satellite or planet. Yet

the difficulty of limiting the cycles is measurably overcome by means of conjunctions or approximate conjunctions among the cosmic bodies; and it is thus that the so-called natural units of time have been developed.

The chronologer takes his primary units from the astronomer; but since there are no aliquot parts in nature he is fain to adjust them to his needs artificially, and so the rotation period of the earth is divided into hours, and these into minutes and again into seconds, and multiplied to form the week; the lunation is transformed into a month; the revolution-period of the earth is sometimes lengthened, sometimes shortened, and converted into a civil year; and the years, civil and synodic, are grouped into natural cycles and artificial eras. So calendars and chronologic eras are developed; and it has come about that ambitious Man has so far arisen above simpler Nature that some of the natural time units are forgotten—modern events are dated by artificial eras in terms of a calendar which most users could not explain without recourse to the dictionary or encyclopedia.

History is a resultant of two forces, one objective, the other subjective—the first is the natural march of events, the second is the series of impressions stamped in the mind by successive events. So history clusters about events of real or fancied import. Among savages, days are reckoned from the great flood and moons from the fear-inspiring eclipse; among barbarians, years are reckoned from the cold winter or the great famine; with the beginning of national organization time is reckoned from the bloody war or the birth of the king, and in a higher stage of intellectual development the reckoning is based on dynasties and the birth of nations; while most of the current bases for historical reckoning are of religious origin. In this way written history is marked by episodes which are grouped into eras, varying with nations and religions, yet commonly reducible to the uniform standard of the chronologer—the historian takes the terms of the astronomer and chronologer as a warp and fills them with the woof of events current and past and thus weaves the fabric of history.

A typical historical era is that of American independence, and in the early days of the republic it was not uncommon to find documents inscribed "In the year of Our Lord seventeen hundred and ninety-two, and of American Independence the sixteenth;" and another typical era is that of the discovery of America by Columbus.

FIG. 1—NATURAL TIM

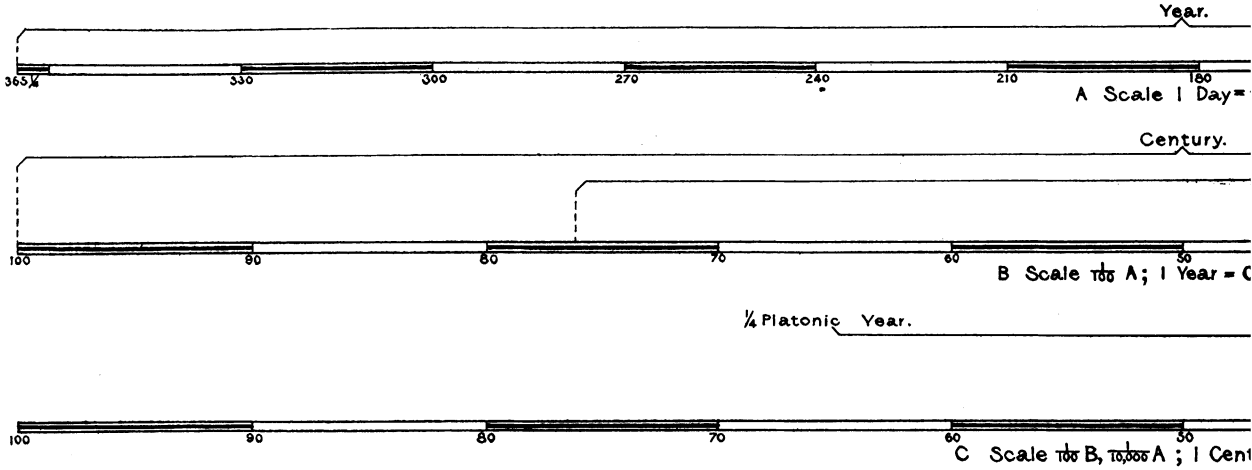


FIG. 2—HISTORIC

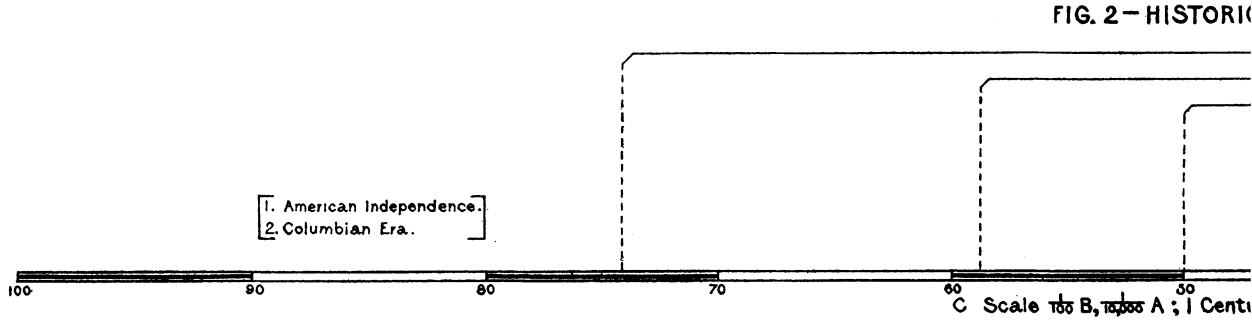
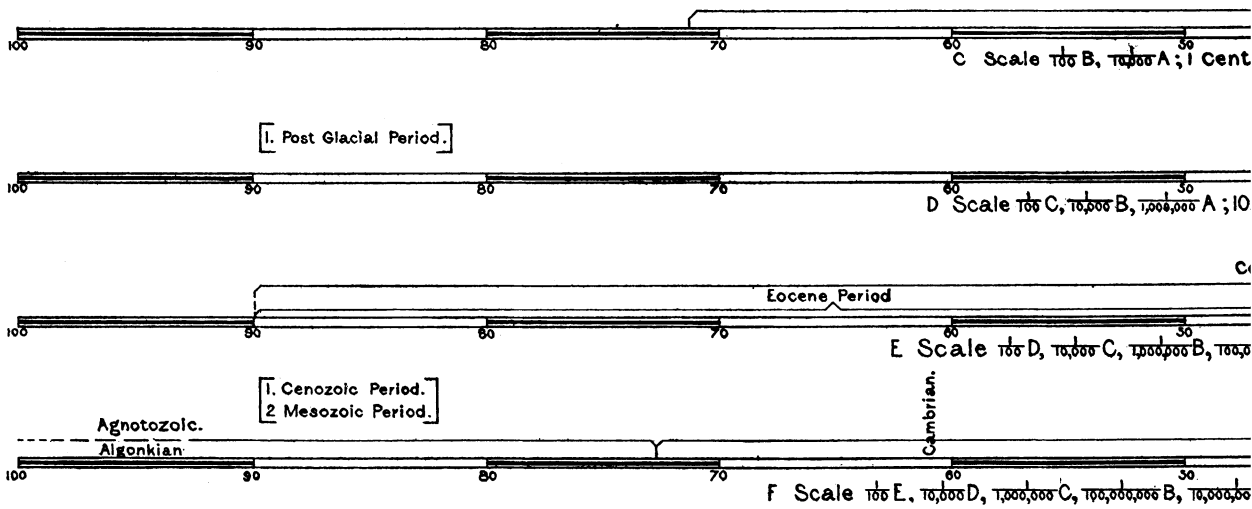
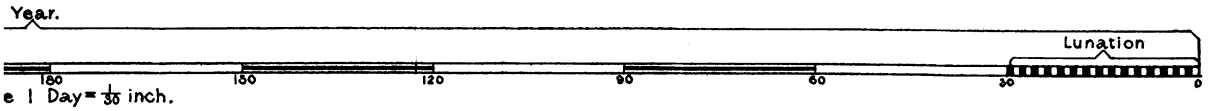


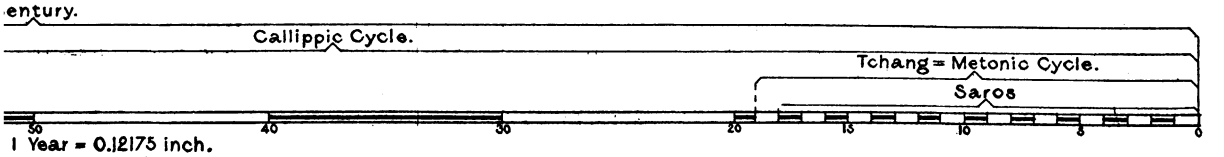
FIG. 3—GEOLOGIC



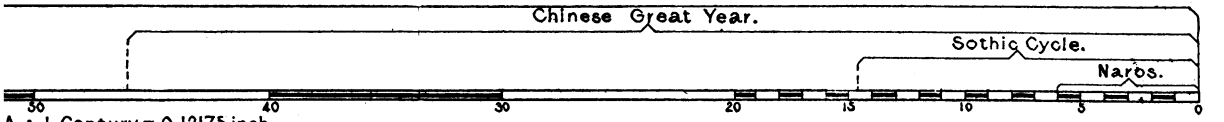
RAL TIME UNITS.



e 1 Day = $\frac{1}{30}$ inch.

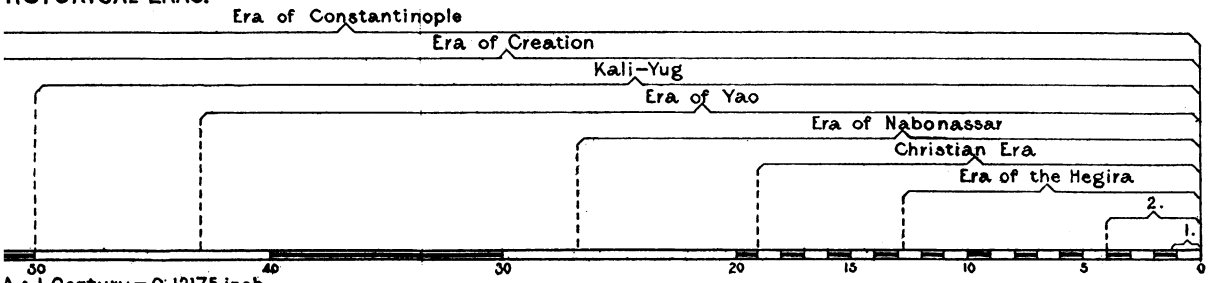


1 Year = 0.12175 inch.



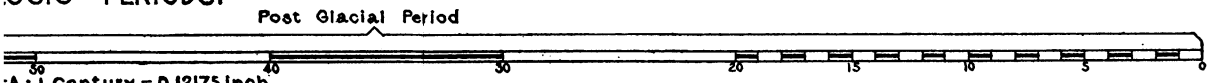
A ; 1 Century = 0.12175 inch.

HISTORICAL ERAS.

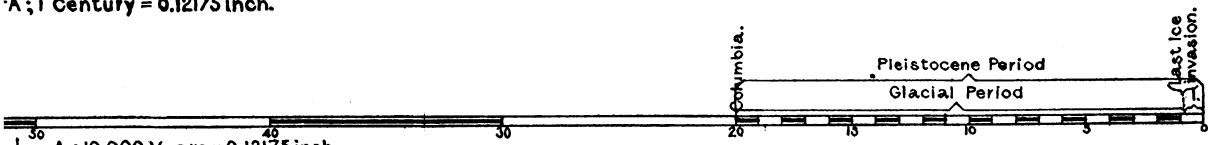


A ; 1 Century = 0.12175 inch.

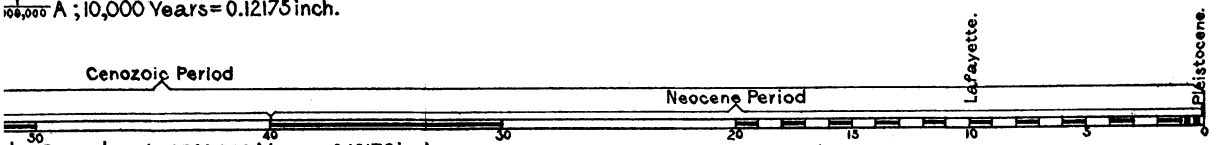
LOGIC PERIODS.



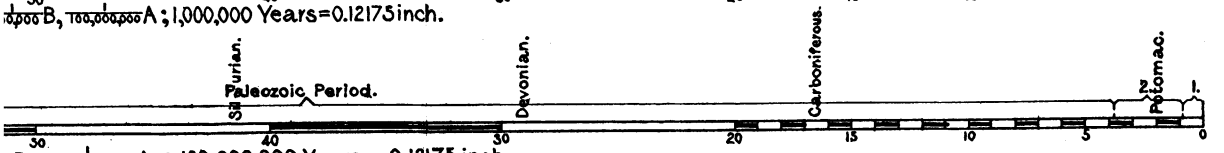
·A ; 1 Century = 0.12175 inch.



$\frac{1}{100,000}$ A ; 10,000 Years = 0.12175 inch.



$\frac{1}{10,000}$ B, $\frac{1}{100,000,000}$ A ; 1,000,000 Years = 0.12175 inch.



$\frac{1}{10}$ B, $\frac{1}{10,000,000,000}$ A ; 100,000,000 Years = 0.12175 inch.

In Persia the current chronology rests on the era of Yezdegird, or Persian Era, and in most Mohammedan countries on the Era of the Hegira, both beginning a millennium and a quarter past; the most widely recognized chronologic period is the Christian Era, now of nearly two millenniums, and chronologers recognize two slightly longer periods in the Augustan and Julian eras; astronomers find the Era of Nabonassar, of which this is the year 2,638, an exceptionally convenient datum point for time-reckoning, while chronologers frequently use the nearly coeval Roman Era and period of the Olympiads; the modern Chinese historian dates by dynasties, but the chronologers run back to the Era of Yao, beginning 4,288 years ago, while the Hindu chronologer reckons from the beginning of the Fourth Era, or Kali-yug (in a series of which the first three are partly fabulous), and of this era 4,992 years are gone; the Jewish Era began 5,651 years ago, and this year, 1892 A. D., is the year 5,895 A. M., or the 5,895th year in the Era of Creation, according to the biblical genesis as interpreted by Ussher; and the longest of the definite historical eras now currently recognized is that of the Greek Church, or Era of Constantinople, beginning 7,400 years in the past.

Such are among the historical eras by which men have measured the flight of time. They may be summarized as follows:

Era.	*Origin.*	*Present length.*
Era of American Independence[1]	A. D. 1776	116 years.
Columbian Era[1]	1492	400 "
Persian Era, or Era of Yezdegird	632	1,260 "
Era of the Hegira[1]	622	1,270 "
Christian Era[1]	....	1,892 "
Augustan Era	B. C. 27	1,918 "
Julian Era	45	1,936 "
Era of Nabonassar[1]	747	2,638 "
Roman Era	750	2,641 "
Olympiads	776	2,667 "
Era of Yao[1]	2397	4,288 "
Kali-yug (Fourth Era)[1]	3101	4,992 "
Jewish Era	3760	5,651 "
Era of Creation (Ussher)[1]	4004	5,895 "
Era of Constantinople[1]	5509	7,400 "

These historical eras, like the natural time-units, may be made appreciable by comparison with familiar space-units. If a day is

[1] Represented graphically in the accompanying plate.

represented by a thirtieth of an inch and a year by a foot, then the Era of American Independence will be represented by the width of a street, and the Columbian Era by a block; on the same scale the Era of the Hegira will be a quarter of a mile, the Christian Era three furlongs, the Era of Nabonassar half a mile, the Era of Yao seven furlongs, the Kali-yug a scant mile and the Era of Creation a mile and a furlong, while the Era of Constantinople will stretch to nearly a mile and a half.

III.—*The Biotic Ages.*

In the beginning of life on the earth the organisms were simple and lowly and left little trace of their existence.

In the second day of the biotic genesis the feeble stream of life divided into plants and animals; some organisms developed stems, leaves and roots, and others made for themselves stony structures such as the cell-walls and calyces of corals and the shells of foraminifera; and many of these structures are entombed among the older rocks of the earth.

Next the shell-fish and their kindred came to prevail, and the vital energy of the planet was chiefly spent in maintaining their supremacy; and this was the day of the mollusk.

In the fourth stage of life on the earth the external stony structures of the prime gave way to internal bony structures, and the vertebrates came into being and soon prevailed throughout the seas; and it was the age of fishes.

Then the seas shrank and the islands grew into continents, and land plants were developed and multiplied until they dominated the earth to the extent that their fossil remains form the fuel of the present; and this day of the plants marks the decline of the reign of the sea and the beginning of the supremacy of the land.

When the sun of the plant day set the power of the plants was lost forever, for with the next age in the genesis of living things birds and beasts were born on the land as well as great reptiles in the sea, and all other things became subordinate to them. The day of land animals was long, and its hours are marked by the rise and decadence of one and another dominant type, each more perfectly adjusted to its surroundings than the old, and each dominating its province or the entire earth throughout its brief ascendancy. There was the hour of the winged reptiles, followed by that of the toothed

birds, and under their reign the trees ceased to live unto themselves but bore fruit to tempt the flying animals, that their seeds might be scattered; there was the hour of insects and insect-eaters, during which bees and beetles fertilized the forerunners of the flowering plants whereby vegetal vitality was in part diverted to the production of flowers and perfumes to gratify animal senses; there was the hour of the gigantic herbivores and of the huge carnivores that feasted on their flesh, and in this hour brute strength prevailed; there was the hour of the feathered bird in the forest and of the timid antelope and the slender gazelle on the plains, and in this hour fleetness prevailed; there was the moment of the American buffalo, during which he multiplied into myriads only to melt away before a changed condition; and the other hours and moments were marked by successive generations of living things, each better than the last. So the animal day was made up of a succession of hours, sometimes serial, sometimes overlapping, but all incommensurable; each hour was characterized by a distinctive vital type, once dominant but now subordinate or gone never to return; and each hour is recorded in the fossils stored up in the rocks. Thus ended the sixth day in the genesis of life.

With the morning of the seventh day cunning appeared, and thenceforth the race was not to the swift nor the battle to the strong; for this was the day of intellect, budding in the beast, blooming in the savage, and fruiting in enlightened Man.

So the record of life read from the fossils entombed in the rocks of the earth falls into a series of biotic ages, or ages characterized by distinctive organic types. This record is the subject-matter of the science of paleontology, and the basis of geologic classification; but it cannot be reduced directly to cosmic or historical units. Yet the record proves that time is long. The improvement of a breed or strain of stock or the development of a new flower or fruit requires generations of culture; the development of a new species without art must require a vastly longer period; and the transformation of organic types upon the earth without the aid of intelligence must involve the birth, growth and death of an incalculable number of generations. Moreover, there is reason for holding that the evolution of organisms has proceeded with ever-increasing rapidity since life came to be on the earth, so that the modern rate would give too low a measure for past time.

Estimated by generations, each day of the biotic genesis is long,

too long for ready realization; but the rhythmic life-waves are not commensurable with the revolutions of cosmic bodies nor with the rotation of planets, and there are no means of directly reducing any biotic age or lesser period to chronologic units. So while the biotic ages are vast, they cannot be expressed in the quantitative language of graphic representation, and may not be compared with space units.

IV.—*The Geologic Periods.*

The sun shines on the earth and the waters of sea and land are evaporated to gather in clouds about the mountain tops and over the plains, and then to return to earth in showers and rain-storms; and as the drops gather into rills and rivulets and eventually into torrents, they collect grains of sand which are washed down the slopes and finally swept into the sea. After a myriad storms and floods the sand grains on the sea bottom are so many as to form a thick and wide-spread deposit; and this is a geologic formation, and the days and years of its accumulation are a geologic period.

As the sand grains are gathered by the storm, gullies are formed, and these are gradually widened into channels in which not only storm-born torrents but peaceful streamlets run; and after a myriad storms and floods the channels expand into great valleys; and the days and years of the scooping out of these valleys make up a geologic period.

Now while the rainfall and the removal of the sand grains result from the sunshine and thus follow the stately march of the daily suns and yearly springtimes, the movements are not commensurable, and no given formation or system of valleys can be correlated with any given cosmic cycle. Yet the mean rate of rainfall has been measured and the mean rate of sand-wash has been computed in many lands, so that the length of the period required for the accumulation of any formation may be estimated, albeit arbitrarily. In this way the time required for the accumulation of the multitude of formations of which the rocks of the earth are composed may be estimated in terms of the natural time-units, and thus in terms of the calendar; and such estimates repay a part of the debt which geology owes to biology for its primary classification, in that they yield a basis for the approximate mensuration of the biotic stages. Moreover the longest of the cosmic cycles is of use in reducing geologic periods to cosmic units; for the Platonic year, like the

annual revolution, has its winter and its summer, and there is reason for supposing that these secular seasons, alternating in each hemisphere at intervals of about 13,000 years, may so modify evaporation, rainfall and snowfall as to yield a record of their recurrence.

The latest definite formation with which American geologists have to deal is a glacial deposit margined by the great terminal moraine stretching from Long Island by way of Cincinnati and Chicago to the international boundary near the base of the Rocky mountains. The antiquity of this deposit, measured by the magnitude of the channels carved within it through the work of rains and rivers, has been variously estimated at from 5,000 to 50,000 or more years, but the later estimates are from 5,000 to 10,000 years, the last and probably the best (recently made by N. H. Winchell) being 7,800 years.[1] On comparing this estimate with the march of the secular seasons a remarkable coincidence is observed; for, since the longitude of perihelion is now 99° 30′, the middle of the last Platonic winter (which is now just begun in the southern hemisphere) occurred about 7,100 years ago. This coincidence at once strengthens the suggestion of interdependence between cosmic and terrestrial conditions, and affords a basis for comparing the natural time-units of the astronomer with the semi-arbitrary periods of the geologist; and so the date of the last ice invasion recorded in the moraine-fringed glacial deposit may provisionally be fixed at 7,100 years ago.

The next older formation with which American geologists are able definitely to deal is the Columbia formation and a coëval glacial deposit not margined by terminal moraines. All competent geologists who have studied these early deposits in connection with those of the later period (including Chamberlin, Gilbert and Salisbury) are agreed that the earlier is many times the older; that if the antiquity of the moraine-margined deposit is represented by unity, the antiquity of the Columbia formation and its correlative glacial deposit must be expressed by two figures. The estimates run from 10 to 100, the mean being about 20 or 30. Now another noteworthy coincidence between cosmic and terrestrial dates is found in this relation; for some 200,000 years ago, or about 28 times further in the past than the date fixed for the last ice invasion, the Platonic winter occurred in the northern hemisphere, and moreover the

[1] American Geologist, vol. X, 1892, page 80.

eccentricity of the earth's orbit was so much greater than now that the conditions for ice accumulation were much more favorable than at any time since or ever before. In this way the supposition that the climate of the earth and the relative positions of the cosmic bodies are inter-related is again strengthened, and at the same time another conjunction between incommensurable cycles is afforded. So the date of the Columbia formation and of the ice invasion to which it is ascribed may be fixed tentatively at 200,000 years ago.

There is a third American formation so conditioned as to yield an exceptionally satisfactory measure of its antiquity; this is the Lafayette formation of the Atlantic and Gulf slopes. Measured simply by the degradation of valleys, this formation would appear to be a thousand times older than the Columbia, but, allowing for certain known differences in attitude of the land with respect to the sea, the ratio may be diminished to 1 : 50. Since in this case no means of applying a cosmic measure has been found, this ratio may be accepted as expressing the relative antiquity of the two formations. Now the Lafayette formation apparently belongs to the Pliocene series of paleontology, or to the seventh or eighth place in a scale of 10 divisions in the geologic group called Neocene, while the Neocene is commonly estimated to be somewhat shorter than the Eocene; and thus the Lafayette formation yields a basis for estimating the period covered by the Cenozoic Age of paleontology. Reducing these estimates to a common standard by means of the significant relation between Platonic years and glacial periods, the date of the Lafayette formation may hypothetically be fixed at 10,000,000 years in the past, while the duration of the Neocene and Eocene respectively will become 40,000,000 and 50,000,000 years, and the beginning of the Cenozoic will be carried back to over 90,000,000 years ago.

Beyond the Cenozoic the data for estimating the geologic periods either relatively or in terms of years are vague, yet many geologists have made the attempt; a conservative relative estimate is that of the venerable Dana, who reckons the Cenozoic, the Mesozoic, and the Paleozoic as far back as the Silurian at respectively 1, 3, and 12. Now the Silurian cannot be far from the middle of the Paleozoic; while beyond lies the Agnotozoic, or age of unknown life—the first day in biotic genesis—which Van Hise and Chamberlin conceive to be fully as long as all the rest of geologic time. So, again reducing the great geologic periods to chronologic units by

means of the provisional measures already adopted in connection with the estimates of Dana and Van Hise (in which due weight appears to be given both to the greater rapidity of physical process and the less rapidity of biotic process in the early ages), the Mesozoic may be assigned a value of nearly 300,000,000 years, while the Paleozoic must be put at not less than 7,000,000,000 years; and this is but half of the time with which the geologist is concerned.

Such vast periods are beyond definite realization; but they may perhaps be made appreciable by comparing them with familiar space units: Let the thirtieth of an inch be a day and let a foot stand for a year; then the remoteness of the last glacial period will be represented by nearly a mile and a half, that of the Columbia formation by a day's drive of about 40 miles, and that of the Lafayette formation by a trans-Atlantic voyage of 2,000 miles; on the same scale the length of the Cenozoic will be two diameters and that of the Mesozoic two circumferences of the earth, while the Paleozoic will be represented by a line long enough to 50 times encircle the globe.

These are the units used by the geologist when he ventures to measure the periods of world growth in terms of cosmic cycles and calendars; but the reduction involves so many unmeasured factors that the conservative student essays it only by way of illustration. The astronomer determines a cosmic cycle with a "probable error" which is commonly a minute fraction of the cycle; the engineer builds a bridge to withstand a strain 3 or 6 or 10 times greater than that to which the structure will actually be subjected, and calls the exponent of the ratio between the calculated strength and the anticipated strain a "factor of safety;" but so uncertain are the relations between the incommensurable season and storm-wash that the estimates of the geologist are subject to a correction far larger than the "probable error" of the astronomer, even beyond the "factor of safety" of the engineer, and moreover this correction—which, unlike that of the engineer, may be either plus or minus—grows with the remoteness of the periods estimated. The geologist's "factor of safety" in estimating the post-glacial period may be but 3 or 4 (*i. e.*, the period may be either 3 or 4 times longer or only one-third or one-fourth so long as the average estimate), yet the estimates of the post-Columbia, the post-Lafayette, the Neocene, the Cenozoic, and each longer period and age require progressively increasing allowances for possible error. Probably the most cautious geologist will be content with a "factor of safety" beginning at 4 for the last

and shortest period and raised to successively higher powers with each successive period and age counted backward into the past, using the second power (16) for the Columbia, the third (64) for the Cenozoic including the Lafayette, the fourth (256) for the Mesozoic, and the fifth (1024) for the Paleozoic. Then the years of the geologic chronology will stand as follows:

Period or Age.	*Mean Estimate.*	*"F. of S."*	*Minimum Estimate.*	*Maximum Estimate.*
Post-glacial period..	7,100	4	1,775	28,400
Post-Columbia.....	200,000	16	12,500	3,200,000
Post-Lafayette.....	10,000,000	64	156,250	640,000,000
Cenozoic age.....	90,000,000	64	1,406,250	5,760,000,000
Mesozoic	300,000,000	256	1,171,875	76,800,000,000
Paleozoic.....	7,000,000,000	1024	6,835,937	7,168,000,000,000
Age of the earth[1]...	15,000,000,000	....	20,000,000	15,000,000,000,000

Such are the periods with which the geologist is accustomed to deal and the units by which he must reckon time; and the later, at least, are minimized even beyond the limit of conservatism.

V.—*The Time Measures of Anthropology.*

Apart from written history, anthropology is without a proper chronology. As among the older forms of life, so among men, generations are born, grow up and die, and stocks are developed and pass away in a series of rhythmic waves or cycles in which no

[1] Eminent physicists, including Thomson (Lord Kelvin), Newcomb and others, have estimated the maximum age of the earth, sun or solar system on the assumption that they are simple cooling bodies at about 100,000,000 years; but since the temperature of the earth (and so the rate of cooling) is materially affected by a complex terrestrial mechanism, and since, in general, the molecular degradation of cosmic bodies is accompanied by an atomic differentiation which must react upon the rate of cooling, such estimates cannot be accepted as final. Eminent geologists have estimated the minimum age of the earth by multiplying the observed rate of sedimentation into the estimated thickness of sedimentary rocks; commonly the rate of sedimentation is assumed equal to the rate of degradation as computed by Humphreys and Abbot, or 1 foot in 6,000 years, or a mile in 31,680,000 years, at which rate nearly 1,600,000,000 years would be required for the deposition of the 50 miles of sedimentary strata among the rocks of the earth; but so many unmeasured or variable factors enter into this estimate that it, also, may not be accepted as final.

point ever returns unto itself and which are not commensurable among each other, nor with the rhythm of geologic process, nor with the cycles of cosmic progression; but the cosmic revolutions on the one hand and the geologic periods on the other yield a chronology to which the development of Man may be adjusted approximately, albeit semi-arbitrarily.

The Age of Man is at once the last of the biotic ages and the beginning of a new era in which the selfish cunning of the beast gave birth to altruistic intelligence, and in which all other living things ceased to live unto themselves and became subservient to the higher power of cultured brain. The hours of the day of land animals were marked by the rise, culmination, and decline of inorganic types each better than the last; but the hours of the day of intellect are marked by inventions and institutions each giving character to countries or the entire world during the period of its dominance. In this way the Human Era has come to be made up of culture stages, sometimes overlapping, sometimes consecutive, and each better than the last—and the later among these stages are the subjects-matter of history. But the way from the bestialities of the prehistoric past to the humanities of history was long and devious, and is inscribed only in the obscure characters of the book of Archeology to which anthropologists and geologists hold keys different, but both required for the unlocking; so that while the later hours of human progress are clearly written, the morning hours and the dawn of the era are enveloped in the mist of remoteness. Accordingly, the earlier records of intellectual development must be deciphered from human relics entombed in the rocks and imbedded in caverns and river-silts before the chronology of Man can be developed, and not until the beginning of the Human Era has been fixed by some definite scale will the chronology be perfect. Thus the goal of anthropic chronology is the discovery of the beginnings of mankind.

In the present dearth of knowledge concerning the earlier stages in human development the antiquity of man may only roughly be estimated by successive approximations made alternately from the standpoints of historian and geologist. Now while an estimate conservative from one standpoint is radical from another, the truth commonly lies well between the extremes; and so a first approximation to an estimate of human antiquity from the points of view of history and geology may be essayed: More than two millenniums past the Chinese and the Hindus were astronomers, and the sages of

the Flowery Kingdom had established an astronomic period of 4,617 years; five millenniums past the builders of the pyramids had established a siderosolar cycle of 1,461 years; and in the absence of correct theory the recognition of at least the latter of these cycles implies empiric observation extending over a vast period. Moreover it is to be remembered that intellectual progress has proceeded with ever-increasing rapidity, that a day of the nineteenth century is even as a thousand years of primitive progress, so that the pre-astronomic portion of human existence must have been enormous. Accordingly it would seem that the records of early chronology carry the origin of man 10,000, or 20,000, or perchance even 30,000 years or more into the past. This estimate may indeed seem excessive when viewed from the standpoint of the written history originating in western Asia and preserved in southeastern Europe, yet it is in harmony with the hieroglyphs of Egypt and the traditions of the Orient. But if the measure of 7,100 years for post-glacial time be accepted, the estimate is radical when viewed from the standpoint of the geologist accustomed to date the origin of man at or long after the last ice invasion of the Pleistocene, for it implies the existence of a semi-civilization, at least, in the Orient and even in Africa while yet Arctic ice overspread northern Europe and America. So startling and distasteful is this conception that most geologists are disposed to carry back the date of this glacial invasion to 20,000, 50,000, or more years in the past. Yet this involves an equally grave difficulty; for even with the lowest estimate of post-glacial time—the unit of the geologic chronology—and with the most conservative estimates of the relative lengths of the greater periods beyond, the geologist is fain to demand many times more centuries for the building of the bedded rocks than the physicist is willing to grant for the cooling of the earth from the molten condition—the leading physicists of the world say that the planet cannot be more than 1,000,000 centuries old, while the foregoing estimate of the geologic periods gives 150,000,000 centuries since the earth divided itself into air, water and land. It is thus that the claims of History, Geology and Physics have to be adjusted and discounted in the common clearing-house of Anthropology.

Howsoever the conflicting claims of rival sciences are weighed, comparison of the several chronologic units yielded by astronomy, history and geology cannot fail to reduce estimates of the geologic antiquity of man. From the standpoint of history it is fairly conservative and from that of geology it is radical to carry man's origin

so far into the past as 20,000 years; but assigning the date of his advent to the beginning of the Pleistocene (*i. e.*, to the end of the Pliocene or the Cenozoic, or to the Columbia period) multiplies that period by 20, and assigning his coming to the Miocene multiplies it by 2,000. From any standpoint this extension of the human period is beyond serious consideration; to prove the Eocene, the Miocene, or even the Pliocene age of man would require more direct, unmistakable and indisputable evidence than would be needed to demonstrate that the pyramid of Cheops was built by steam hoisting machinery and the Chinese wall by the electric light. Moreover, viewed from the common standpoint of stratigraphic geology and paleontology, the improbability of human existence in the early Tertiary waxes well toward impossibility; for, as Boyd-Dawkins has repeatedly pointed out, *Homo sapiens* represents the culmination of a long line of evolution toward which the mammalian forms of the Pliocence had scarcely begun to point, yet all of these simpler and stabler organic types have faded with the flight of the Cenozoic eons. So while the antiquity of man may perhaps safely be carried 20,000 years into the past and that of the unknown anthropoid progenitor perchance as much farther, it is inherently improbable that real man existed beyond the middle of the Pleistocene, and inherently incredible[1] that he was born before the Pleistocene began.

[1] Inherent, or *prima facie*, or *a priori* incredibility is not to be confounded with impossibility. When a traveler through a previously unexplored country reports that the savage natives sometimes fell trees across streams for bridges, the report is inherently probable and is quoted without question, because that is the way of primitive peoples; if he states that the streams are spanned by stone arches, the statement is commonly regarded as inherently improbable and is not quoted without question, because savages are not known to understand the principle of the arch; if he announced the construction by savages of a stone arch of 250 feet span, the announcement would be inherently incredible, because it would imply engineering skill equal to that of the enlightened builders of the Trezzo Bridge of the Lombards and our own Cabin John Bridge, the longest arches in the world; while if he recorded the existence of a stone arched bridge of 2,500 feet span, his record would be rejected on the ground of impossibility, because stones are not strong enough to sustain an arch of that length. Yet he could surmount the inherent improbability in the second case by limited corroborative testimony, and the inherent incredibility of the third case by suitably designed photographs and other collateral representations in connection with that complete consistency of narrative which is commonly accepted as inherent evidence of veracity.

In the morning of the last day in the development of life on the earth cunning was born and prevailed; but the way from the cunning of the fox to the craft of the anthropoid was long, and it was well toward the present high noon of the day of intellect before bestial craft blossomed into the primitive genius that invented or enslaved fire and kindled the flame of humanity; and the rising hours of the forenoon may be estimated but not yet measured.

NOTE.—The several time divisions described are represented graphically in space units in the accompanying plate. Fig. 1 represents the natural time-units, Fig. 2 the historical eras, and Fig. 3 the geologic periods; but by reason of the wide range in values it has been found necessary to use six different scales in the diagrams. The first diagram is drawn to the scale used in the text for expressing time-units in terms of space units, *i. e.*, a thirtieth of an inch for a day and a foot for a year; and this is designated scale *A*. The successive scales indicated by the letters *B*, *C*, *D*, *E* and *F* are each one-hundredth of the next preceding scale. In scale *C*, which is used three times, a century is about an eighth of an inch, and a hundred centuries, or ten thousand years, is a foot.

RAISING AND FALLING OF THE SKY IN IROQUOIS LEGENDS.—In many of the Iroquois myths of the journeys of men and disembodied spirits to the Land of Souls, it is asserted that the sky raises and falls at the point of egress from this world, and that spirits which have not fulfilled their duties in this life are crushed by the impact of the sky at this passage. The origin of this notion seems to be in the fact that the fitful coruscations of the aurora borealis or northern lights dance over the nebulæ of the night, a phenomenon that they may have supposed was caused by the raising and falling of the sky, not suspecting that their explanation of the cause of the dancing of the aurora was a subjective notion. Confirmative of this explanation of the belief in question is the fact that usually this passage is located in the extreme northwest.

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TABU OF THE COW BY THE SHÎNS.—The noble caste of Shîns of Dardistan, who were expelled by the Brahmins from India or Kashmîr, held the cow in abhorrence as one of their religious dogmas, whereas in other ways they are really Brahmins, among whom Hindooism is found peeping out through the thin crust of Mohammedanism.—(LEITNER in Trans. Victoria Inst., xxiii, No. 90, p. 120.)